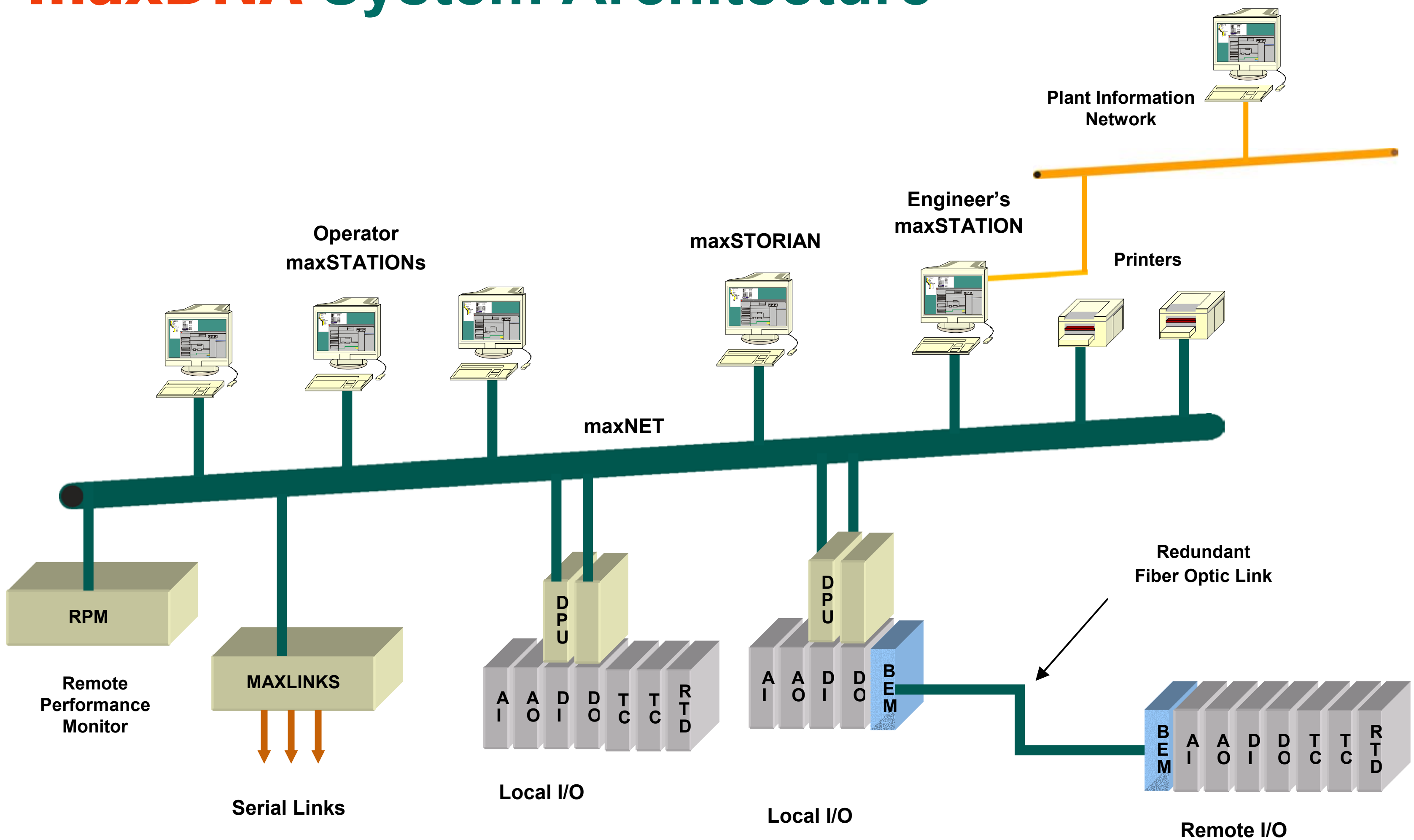
Metso Automation

Your Global Supplier of Automation and Information Management Systems for the Power Automation Market

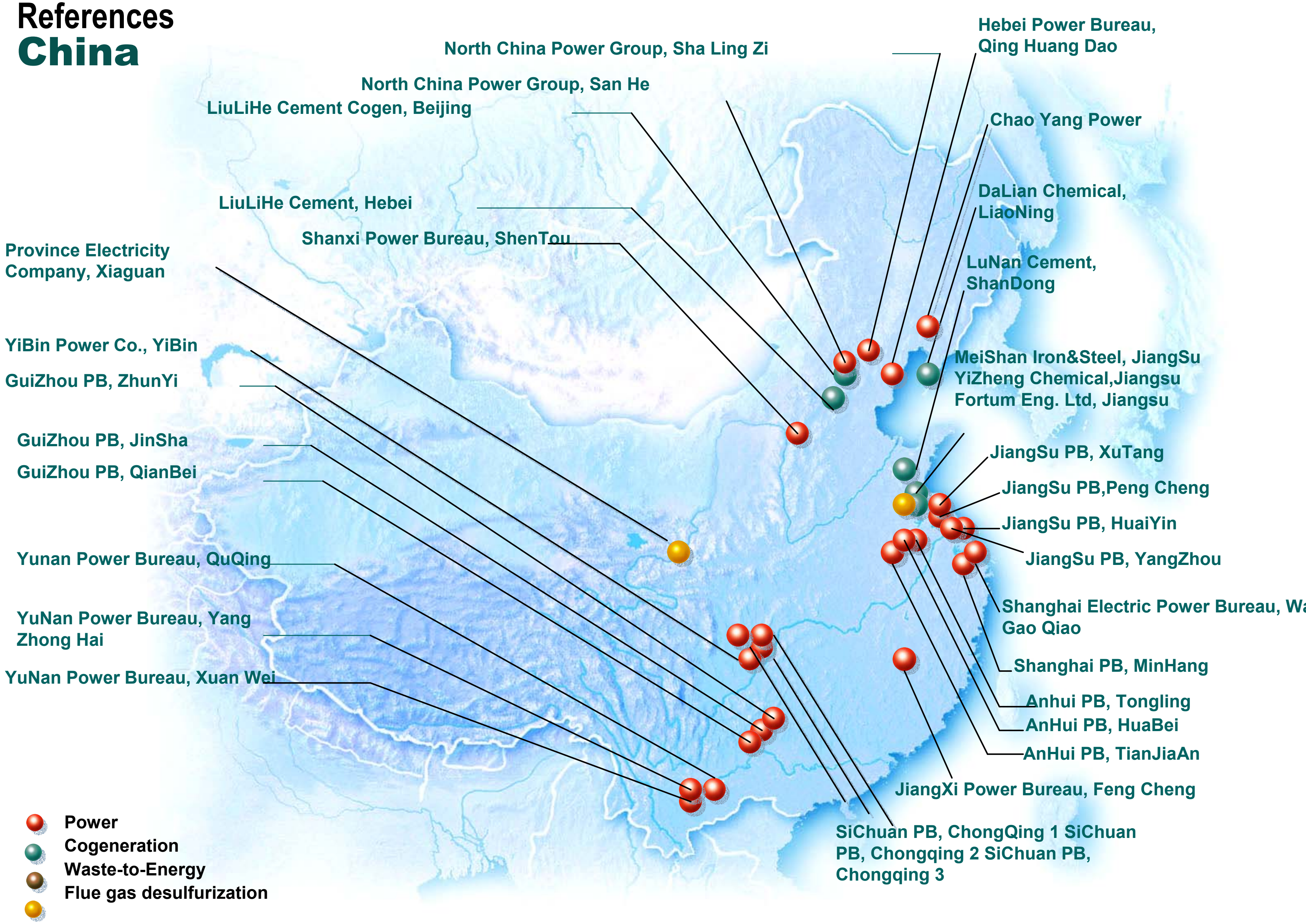
metso
automation

maxDNA System Architecture



metso automation

References
China



metso automation

maxDNA

Leading DCS Technology

with

> 70 Generating Units on Control in China

and

22 Industrial Projects

China Power Installations

Province	Plant	Size (MW)	Year
Anhui	TianJiaAn upgrade 1 x 300MW (Boiler, Turbine, EMCS)		2003
Sichuan	YiBin 410 t/h CFB new (Boiler, Turbine, EMCS)	1 x 100	2003
Yunan	XuanWei Phase VI new (Boiler, Turbine, EMCS, DEH, ETS, Simulation)	2 x 300	2003
Yunan	XunJiangSi new 440 t/h CFB (Boiler, Turbine, EMCS, DEH)	1 x 125	2003
Yunan	XiaoLongTan retrofit (Boiler, Turbine, EMCS, DEH)	1 x 100	2003
Yunan	KunMing retrofit (Boiler, Turbine, EMCS, DEH)	1 x 100	2003
Anhui	TianJiaAn retrofit (Boiler, Turbine, EMCS, DEH)	1 x125	2002
Guizhou	QianBei Units 1 & 2	2 x 300	2002
Shanghai	WaiGaoQiao Phase 1 Simulation 4 x 300MW		2002
Guizhou	ZunYi Unit 2	1 x 125	2001
Jiangsu	YangZhou Unit 4	1 x 200	2001
Shanxi	ChaoYang	1 x 200	2001
Sichuan	ChongQing No. 3	1 x 200	2001
Anhui	HuaiBei	1 x 200	2000
Anhui	TianJiaAn includes DEH	1 x 125	2000
Jiangsu	XuTang	2 x 300	2000
Jiangsu	YangZhou Unit 5	1 x 200	2000
Jiangsu	HuaiYin Unit 2	1 x 200	2000
Sichuan	ChongQing Unit 2	1 x 200	2000
Jiangsu	YangZhou Unit 6	1 x 200	1999
Shanghai	MinHang	1 x 125	1999
Sichuan	ChongQing Unit 1	1 x 200	1999

metso automation

China Power Installations – cont'd			
Province	*Plant*	*Size (MW)*	*Year*
Jiangsu	HuaiYin Unit 1	1 x 200	1998
Sichuan	YiBing Unit 2	1 x 200	1998
Yunnan	XuanWei	2 x 300	1998
Yunnan	YongZhongHai Unit 2	1 x 200	1998
Anhui	TongLing Unit 1	1 x 300	1997
Beijing	SanHe I&C Island	2 x 350	1997
Guizhou	JinSha	4 x 125	1997
Guizhou	ZunYi Unit 1	1 x 125	1997
Hebei	ShaLingZi	4 x 300	1997
Jingxi	FengCheng B	2 x 300	1997
Sichuan	YiBing Unit 1	1 x 200	1997
Shanxi	ShenTou Unit 1	1 x 500	1996
Jiangxi	FengCheng A	2 x 300	1995
Yunnan	QuQing	2 x 300	1995
Anhui	TianJiaAn	1 x 300	1994
Jiangsu	PengCheng	2 x 300	1994
Yunnan	YongZhongHai Unit 1	1 x 200	1994
Hebei	QingHuangDao	2 x 300	1993
Shanghai	WaiGaiQiao	4 x 300	1992
	Total	***59 Units 13,475 MW***	

metso automation

China Process Industry Installations			
Province	**Plant**	**Process**	**Year**
Shanghai	JinShan Petrochem	upgrade	2002
Shanghai	JinShan Petrochem	expansion	2001
Shanghai	JinYang	Acrylic Fiber	2000
Jiangsu	MeiShan Iron & Steel	Cogen	1999
Hebei	HeJian Chemical	Chemical Prod’s.	1998
Jiangsu	MeiShan Iron & Steel	Cogen	1998
Liaoning	DaLian Chemical	Cogen	1998
Jiangxi	JiuJiang Petrochem.	Chemical Prod’s.	1997
Shandong	LaiWu Iron & Steel	Boiler Control	1997
Shanghai	JinShan Petrochem	Acrylic Fiber	1997
Yichang	YiChang Chemical	Urea Production	1997
Liaoning	DaLian Chemical	Cogen	1996
Jiangsu	YiZheng 2x50MW	Cogen	1996
Shanghai	BaoShan Iron & Steel	Furnace Control	1996
Fujian	XiaMen Glass 2	Glass Line	1995
Hubei	DaYe Smelter	Furnace Control	1995
Shanghai	JinShan Petrochem	Acrylic Fiber	1995
Shanghai	BaoShan Iron & Steel	Furnace Control	1995
Hebei	LiuLiHe Cement	Cogen	1994
Fujian	XiaMen Glass 1	Glass line	1993
Jiangsu	YiZheng	Fiber line	1993
Shandong	LuNan Cement	Cogen	1993
Shanghai	Baoshan Iron & Steel	Furnace Control	1993
Shanghai	JinShan Petrochem	Acrylic Fiber	1993
Shanxi	LuCheng Cement	Cement Prod’s.	1992
Anhui	ChaHu	Cement Prod’s.	1991

metso automation

Information Technology

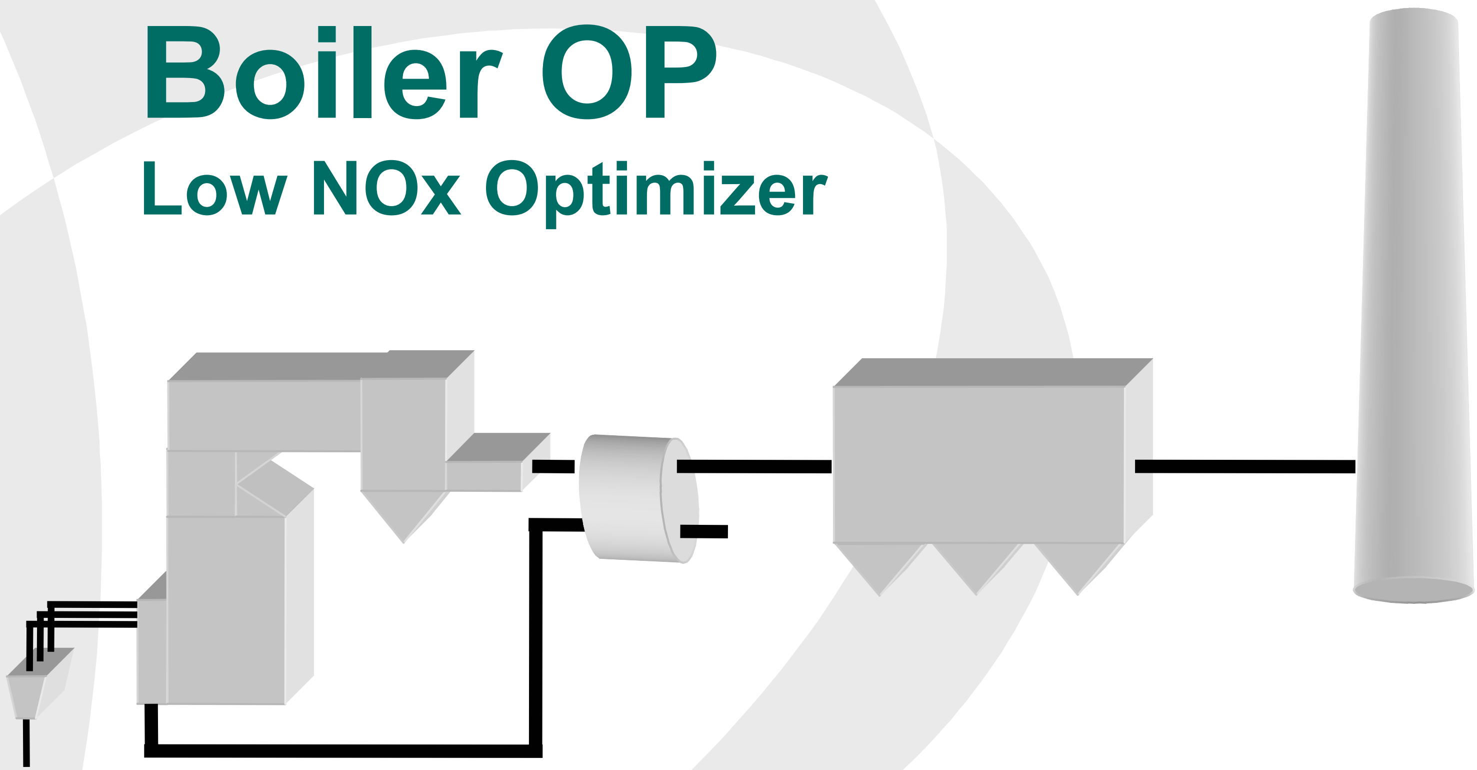
SIS Application

Optimizes the Relationship between

Heat Rate vs NOx production

Boiler OP

Low NOx Optimizer



The social costs of burning fossil fuels….

- SO_2 formation in fluegas
- NO_X formation during combustion process
- Heavy metals (Hg and arsenic)

All require a different means to control….

In addition there are greenhouse gases such as CO_2

metso automation

NO_X reduction categorized by two methods..

1. Out of furnace - SCR

2. In-furnace

   - Fuel switching
   - SNCR
   - Reburn
   - Low NO_X burners
   - ***Combustion optimization***

metso automation

“In-furnace” NOx Reduction

- Stack emissions are over 95% of NOx
  - NO - Nitrous Oxide
  - NO_2 - Nitric Oxide
- Types of NOx production
  - **Thermal NOx** formed through natural combination of Nitrogen and oxygen during combustion process
  - **Fuel NOx** formed from nitrogen embedded in fuel
- Natural gas has lowest NOx formation - all is fuel NOx
- Oil
  - **Thermal NOx** 20-40%
  - **Fuel NOx** 60-80%
- Coal
  - **Thermal NOx** 10-20%
  - **Fuel NOx** 80-90%

metso automation

NOx Formation in a Boiler

How is NOx formed?

$N_2 + O_2 \rightarrow NO_x$

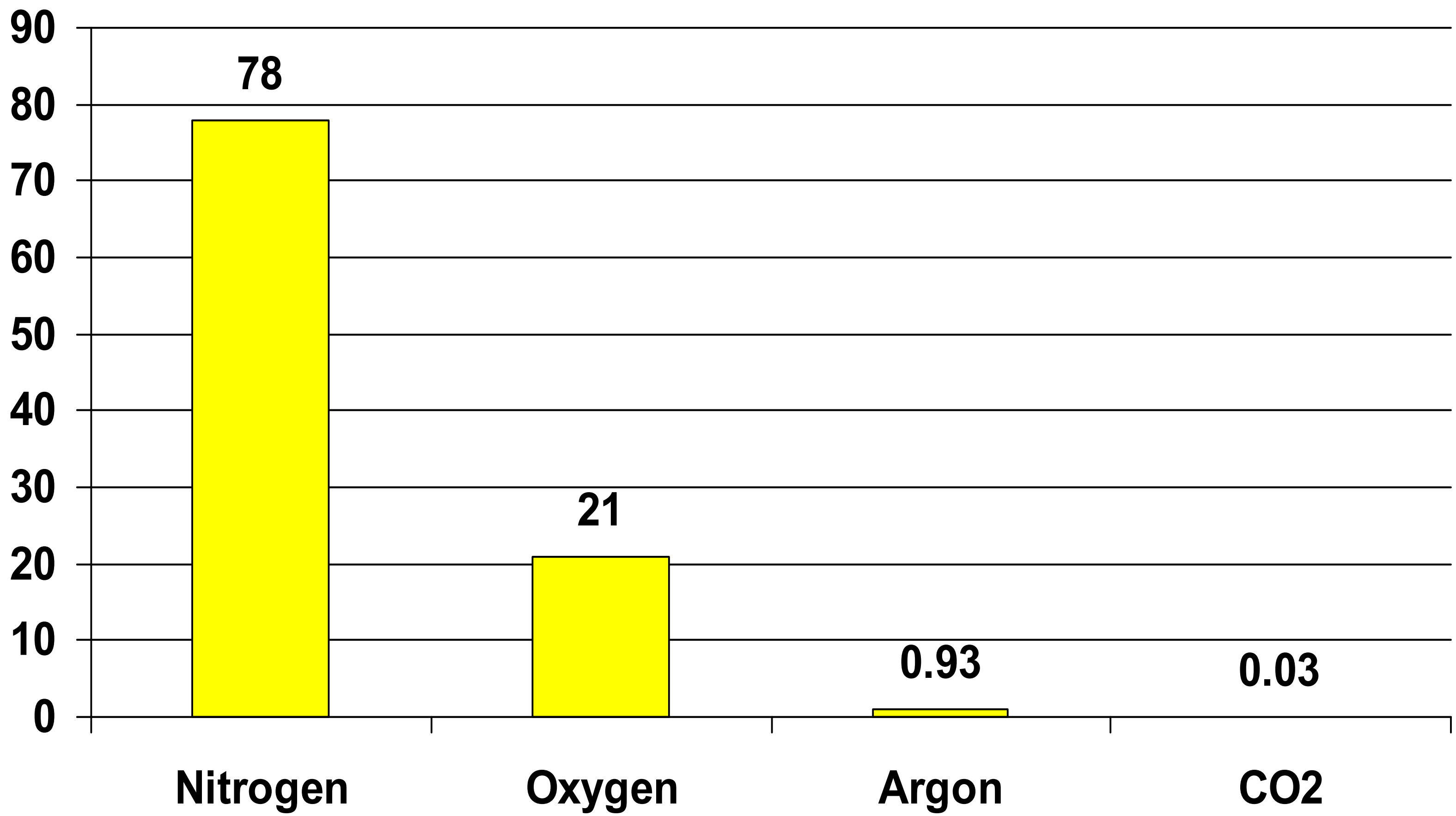
- **Thermal NOx** - High peak flame temperature combines atmospheric nitrogen and oxygen.

  20 - 40% of total
  - Increases exponentially with temperature.
  - Proportional to the square root of oxygen content.
- **Fuel NOx** - Formed from Nitrogen in fuel.

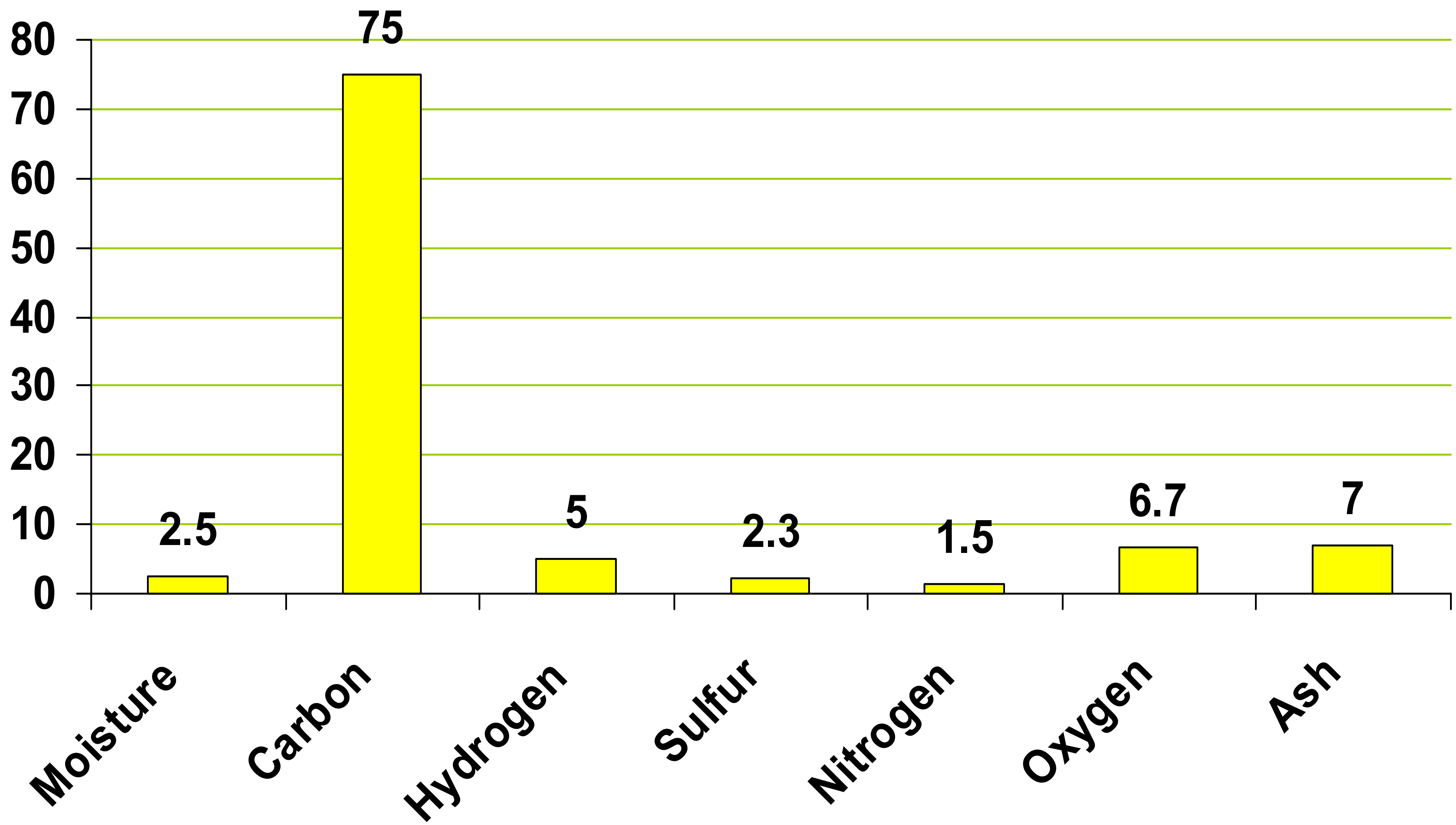
  60 - 80% of total
  - Increases rapidly with oxygen rich atmosphere.
  - Decreases with delayed mixing.

metso automation

Composition of Air...



Western PA Bituminous Coal
Heating Value 13,000 BTU per pound
Percent by weight



Factors affecting NOx formation...

- **Temperature** is key (>1800° starts NOx formation)
- **Time** (longer the burn the less NOx)
- **Turbulence** (mixing of fuel and air is critical)

metso
automation

NOx formation as a function of temperature

- Most NOx above 1800°F
- Minimize NOx by keeping average flame temperature low
- Use the same heat in the process, just make the burnout longer
- Flame is lengthened - provide more time for burnout, which lowers combustion temperature
- Larger furnace cavity is required to lower NOx

NOx formation as a function of time

- Longer time required for fuel burn out produces lower NOx levels
- Complete burnout is important (particle size should be minimum)
- Must set classifier for smallest particle size
- Fuel/air mixing rate regulates the burn rate and thus the resulting average combustion temperature

Turbulence...

- Necessary for mixing fuel
- Excessive turbulence promotes rapid burnout and high average combustion temperature
- Low NOx burners mix fuel and air in stages and quantities for low NOx production
- Goal: reduce air to core burner zone

metso automation

Reduce air in core burner area….

- Go to 90% of stoichiometric air requirements in core burner area - total still at at least 130%
- High NOx burner produces:
  - High temperature
  - Blue to clear flame
  - Quick time
  - Turbulent mixing
  - Short flame

metso automation

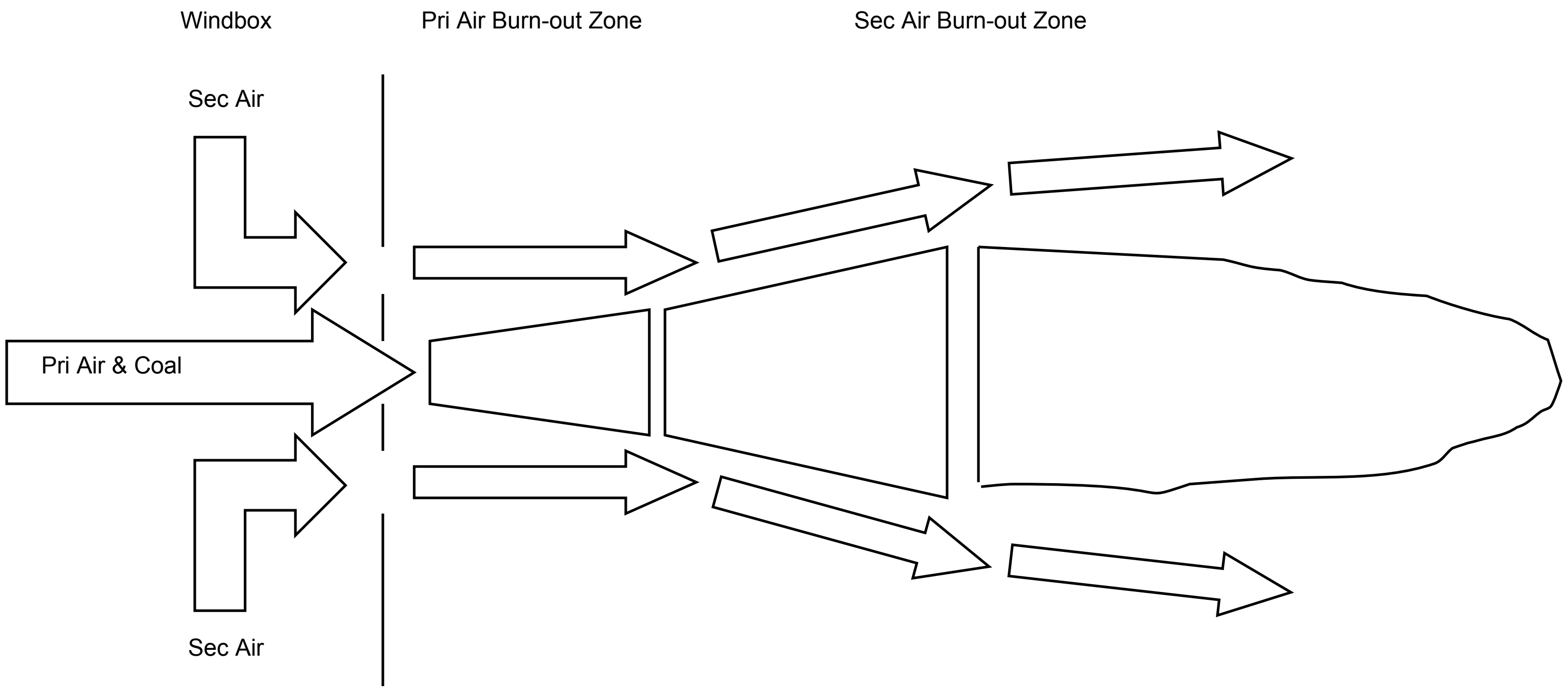
Low NOX burners make flame long and lower temperature...

- Low peak flame temperature
- Flame is yellow
- Gradual burn
- Temperature on the other side of furnace will increase
- Controlled mixing of fuel and air

Stoichiometry & NOx

- 100% is 1.00 ratio of moles of fuel to oxygen
- Excess air is additional over this amount
- <100% at the burner area results in lower temperature
- remaining air is injected as overfire air at top of furnace
- Total air flow to furnace is still greater then stoichiometric

Low NOx Burners extend flame pattern and lengthen burn-out time



NOx influenced by...

- Incorrect Boiler Control Settings
  - O_2 Levels
  - Secondary Air Damper Positions
  - Burner Tilts
  - Overfire Air Damper Positions
- Boiler Air Leakage
- Dirty Boiler
- O_2 Sensor Problems
- CEM System Problems

metso automation

Why Optimize Combustion?

- **Reduce NOx** – 20% to 35% Reductions
  - with Conventional or Low NOx Burners
- **Improve Heat Rate** – 50 to 100 Btu/kWh
- Reduce LOI to Sell Fly Ash
- Reduce Potential for Severe Slagging
- Eliminate Opacity Excursions

Enhances the performance of Low-NOx Firing Systems

metso automation

Optimization Objectives

Objectives are specific to the unit and situation

- Lowest Possible NOx
- Control NOx to Target
- Minimize Heat Rate (Increase efficiency)

Constraints can be applied

- LOI
- CO
- Opacity
- Steam Temperatures
- Gas Temperatures

metso automation

Combustion optimization uses a mathematical model of process...

- Software based
- Calibrates final control elements
- Learns process and improves upon model as it learns
- Can be closed loop or operate in supervisory mode

metso automation

Combustion Optimization

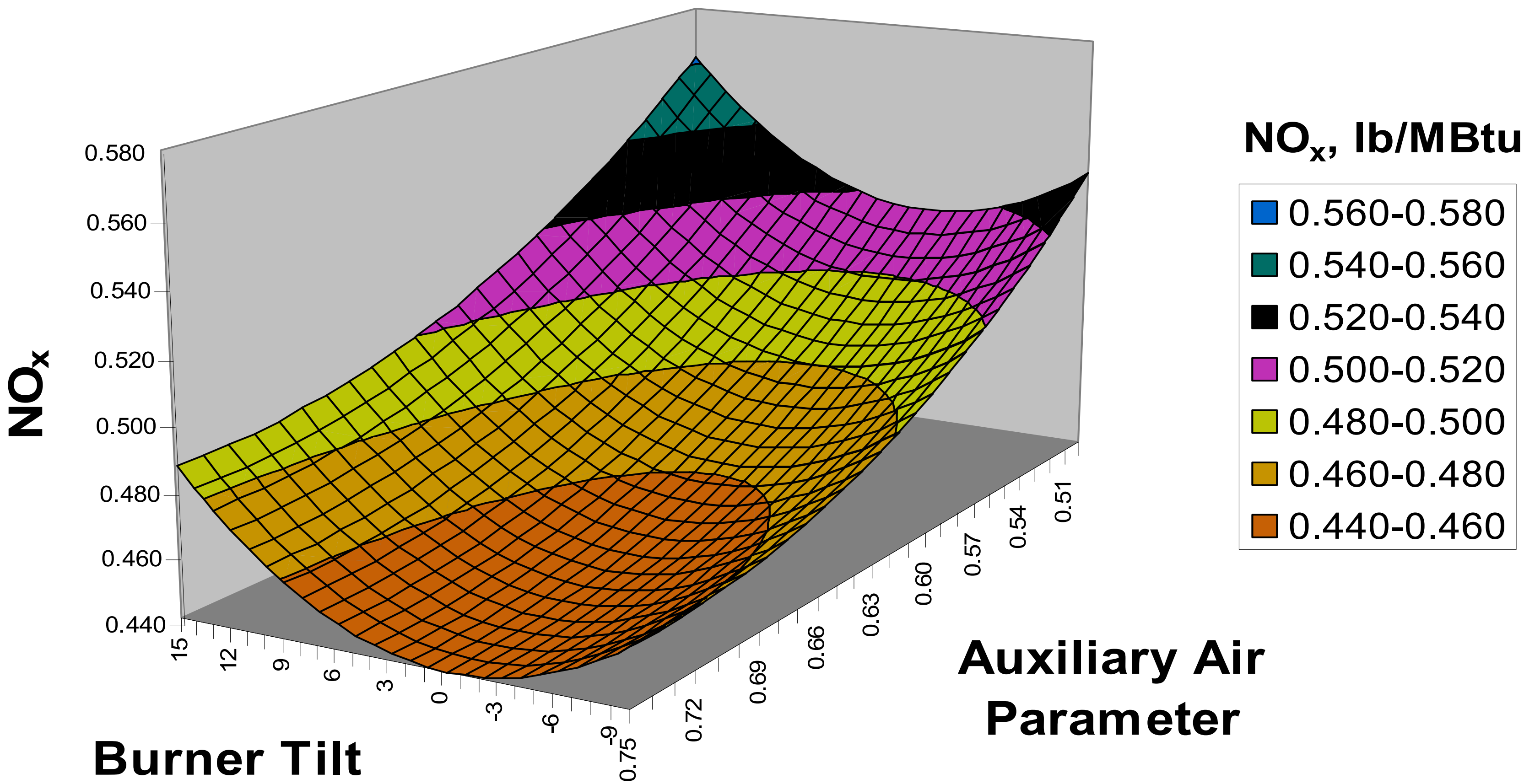
- Determines the best combination of:
  - Fuel-Air Mixing Patterns
  - Furnace O_2 Levels
  - Furnace Temperatures
- Solves for the Optimization Objective
- Applies Constraints
- Adjusts Boiler Control Settings

Optimization: A Complex Problem

- Too many variables to solve for the optimum combination by intuition or ‘by inspection’
  - Furnace O_2 Level
  - Burner Tilt Angle
  - SOFA Tilt Angle
  - Windbox Pressure
  - Mill Loading Pattern (biases)
  - CCOFA Damper Positions
  - Boiler Cleanliness
- People can’t visualize more than 3 variables

metso automation

Parametric Relationships



What is Boiler OP?

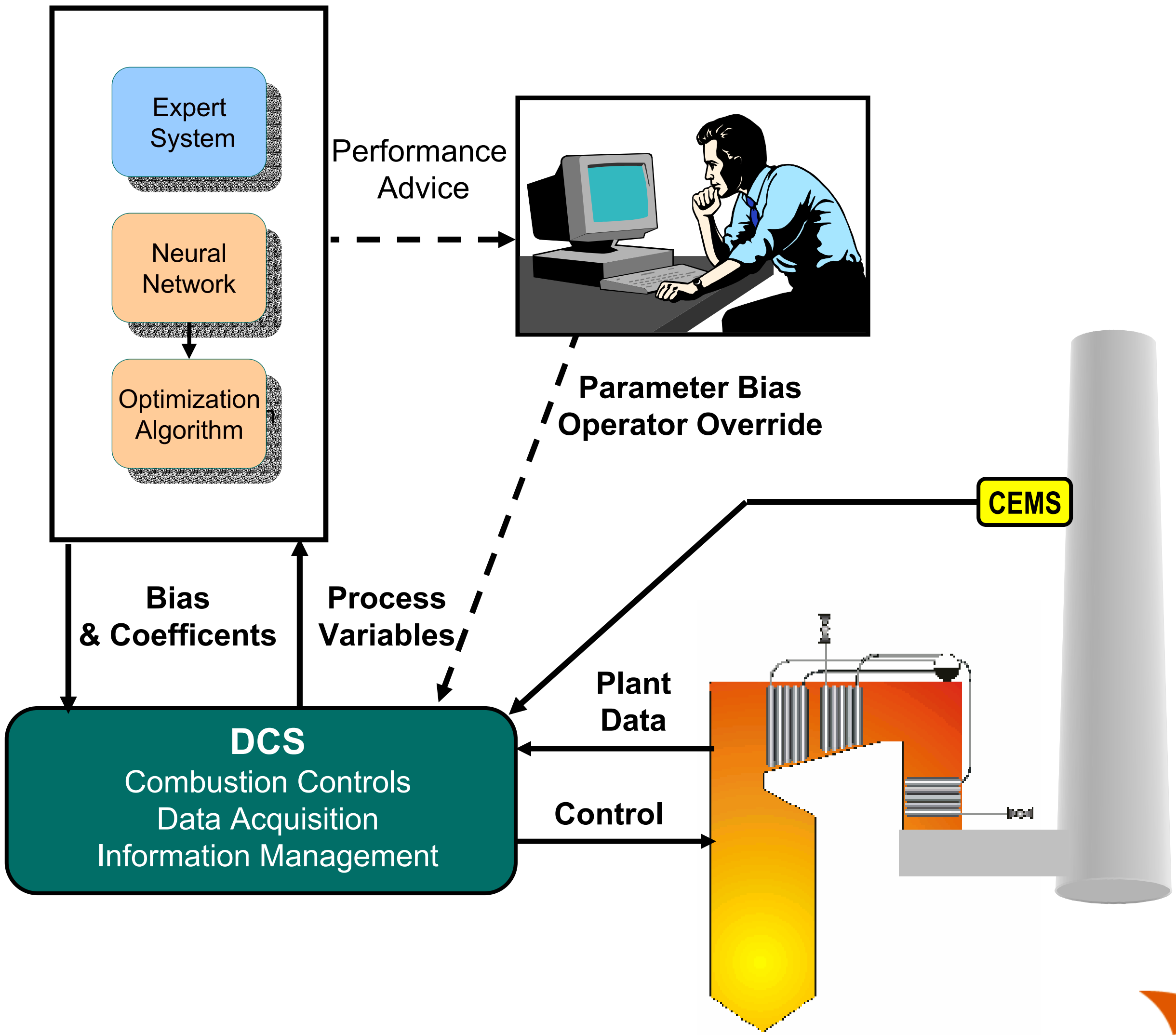
- Boiler OP is a Neural Network based Combustion Optimizer.
- Boiler OP calculates optimal settings for the controllable parameters.
- Boiler OP presents on-line information to the operator and can adjust the boiler control settings in closed loop mode.
- Boiler OP evaluates current operating conditions and predicts the impact on performance.

metso automation

Boiler OP Background

- Developed by Lehigh University Energy Research Center and Potomac Electric Power Company
- Over 10 years of experience in the application of Neural Networks to Combustion Optimization
- Over 20 Boiler Optimization projects on boilers of different sizes, geometries, and fuels
- Over 40 Professional Staff, Faculty, and Grad Students
- Extensive work with EPRI on Heat Rate Calculations and Performance Measurements

Boiler OP Structure



Anatomy of an Optimization Project

… see the paper

Optimization Project Sequence

Step 1: Prepare for Testing

check instrumentation, inspect boiler, check burners & mills

Step 2: Conduct Parametric Tests

Step 3: Build Database

Step 4: Correlate Data Using Neural Networks

Step 5: Determine Optimal Solutions

Step 6: Convert Results into Control Curves

Step 7: Configure the Operator Displays

Step 8: Install Software & Validate Model

Step 9: Train Operators

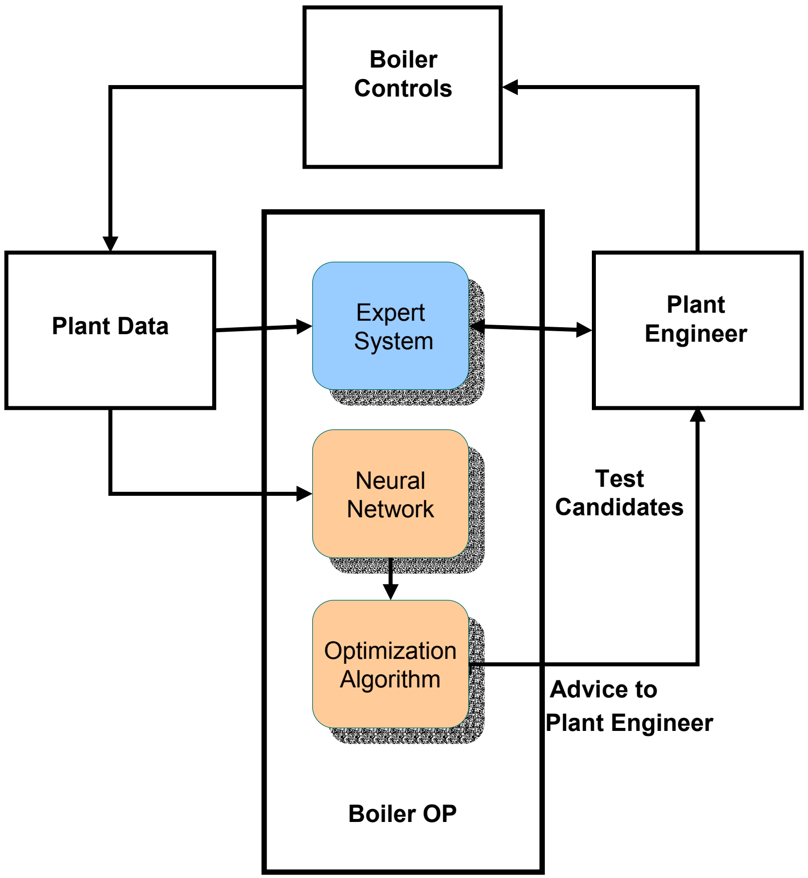
metso automation

The Importance of Proper Testing

- Neural Networks use a database to build a model.
  - Without good data, the model is not correct.
- Neural Networks can not distinguish between good data and bad data.
  - A good model can be contaminated by bad data
- Neural Networks can not accurately extrapolate beyond the range of test data.
  - Must be able to find the global optimum, not just local
- All operating constraints must be considered.
  - The goal is a physical optimum, not just mathematical

metso automation

Parametric Testing



- An Expert System establishes test criteria & guides the test engineer through the test sequence
- Test progress is logged and advice is presented to the test engineer
- The Expert System is based on 15 years of combustion optimization experience

metso automation

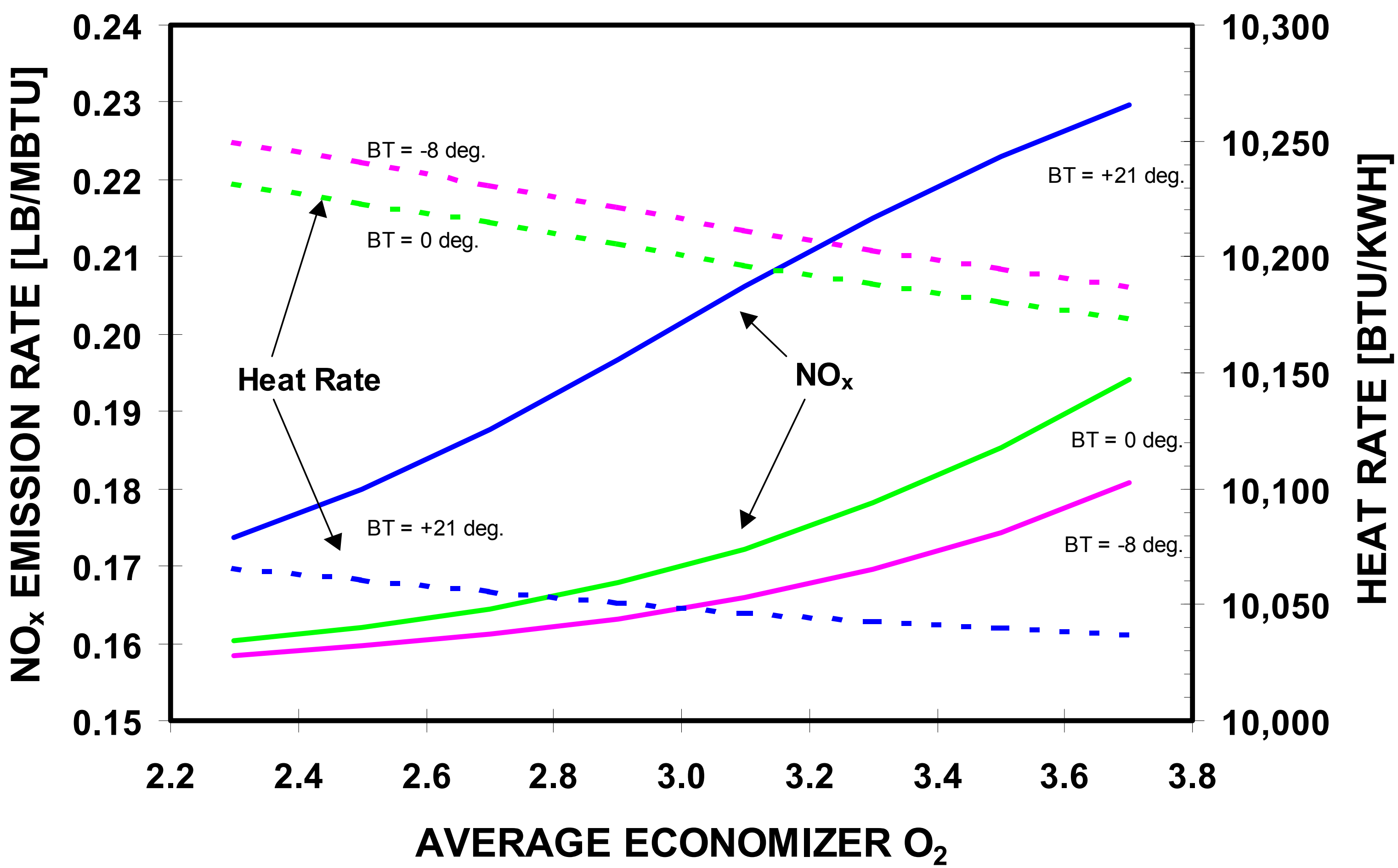
Parametric Relationships

- Relationships developed through parametric testing are complex*!*
- Boiler OP uses Neural Networks to correlate key parameters to boiler control settings
  - $NOx = f(O_2, Tilt, \ldots)$
  - $Heat\ Rate = f(O_2, Tilt, \ldots)$
  - $LOI = f(O_2, Tilt, \ldots)$
  - $Opacity = f(O_2, Tilt, \ldots)$

Optimization Algorithm

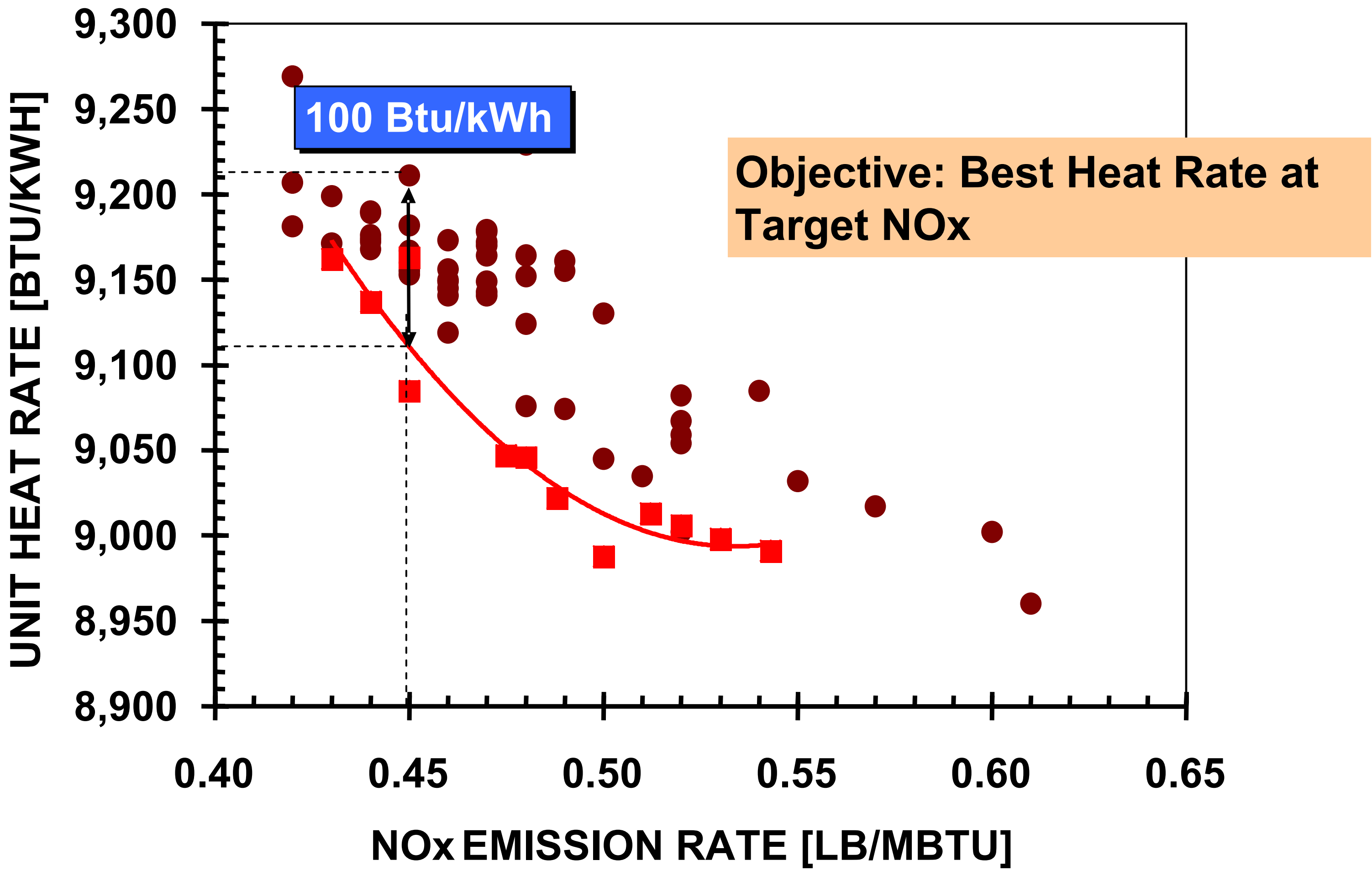
- Applies a mathematical optimization algorithm to the neural network model to determine optimal boiler control settings
- Enforces operating and safety limitations on the optimal boiler control settings
- Displays optimal boiler control settings to the user

Neural Network Predictions



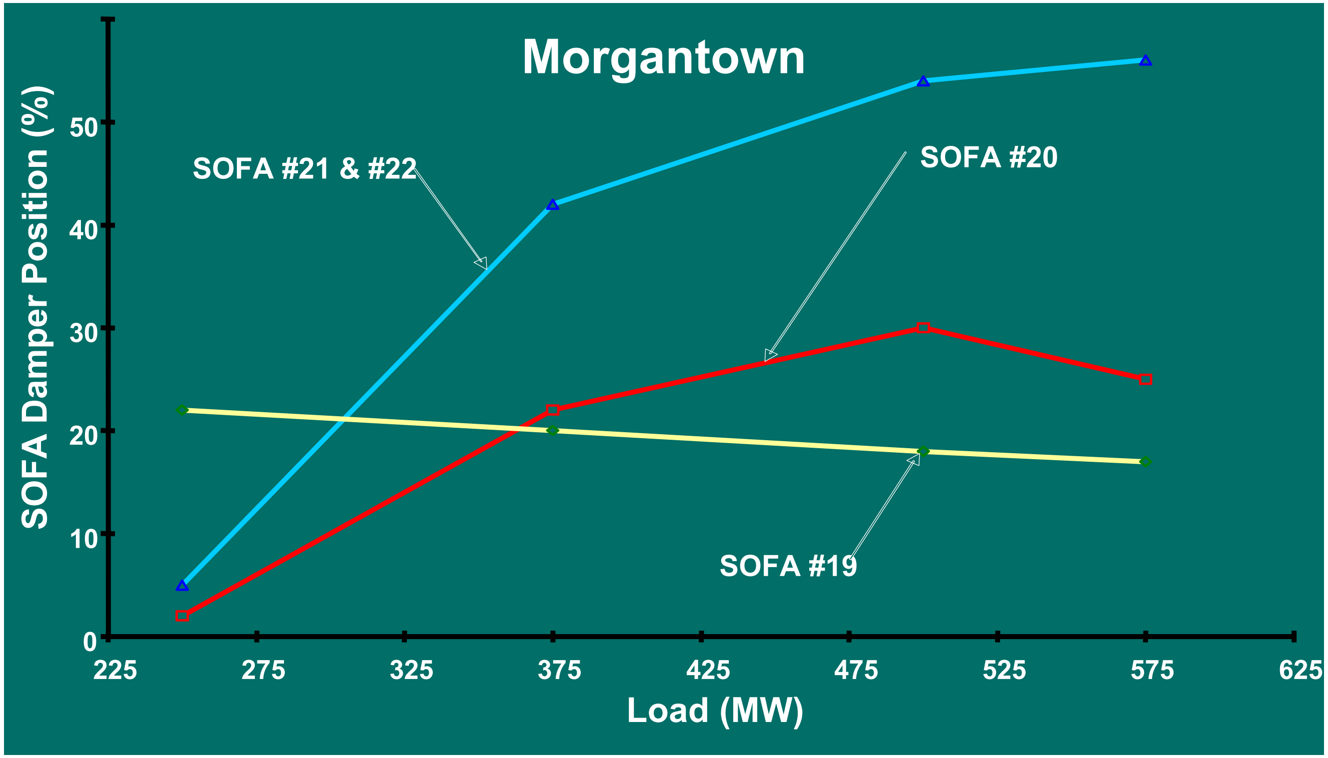
Optimization Algorithm Results

Potomac River Station



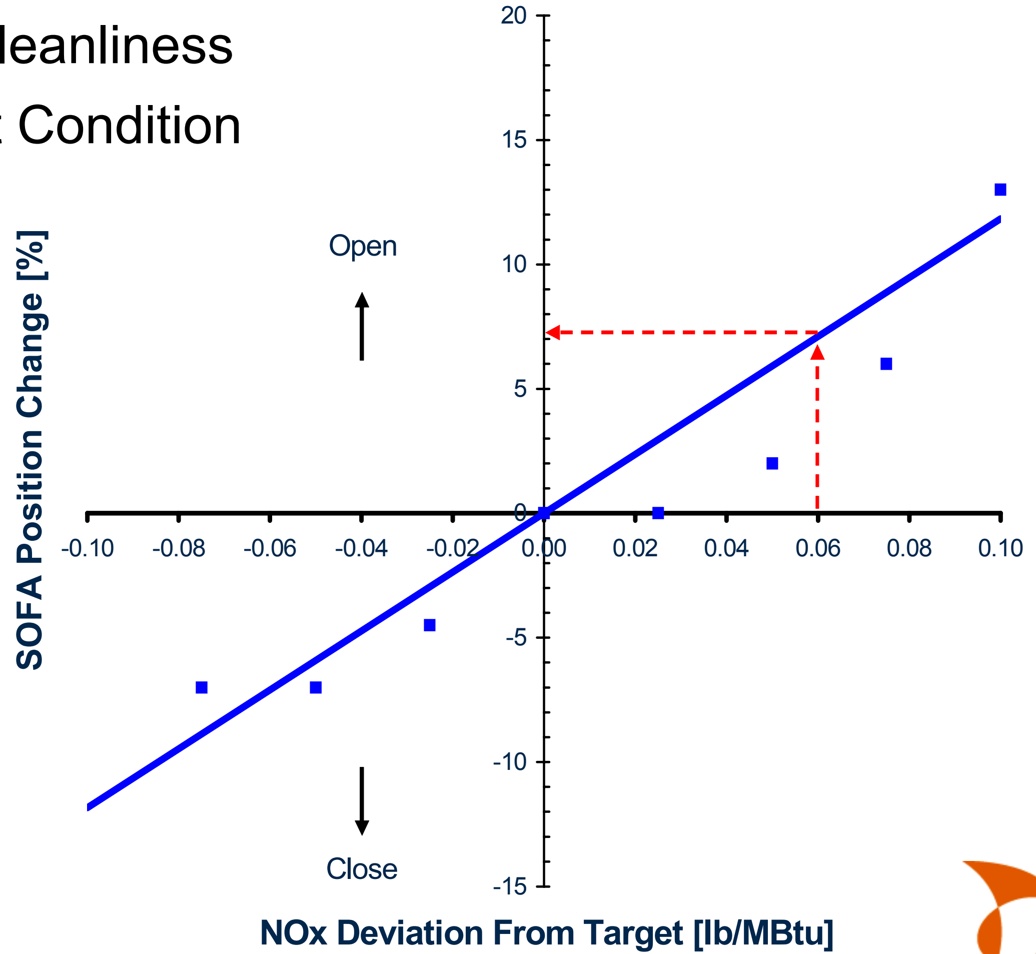
Closed Loop Control

- Control Curves are generated for key parameters
- Setpoints are determined by the optimization objectives & constraints
- Control Curves are configured into the combustion control system

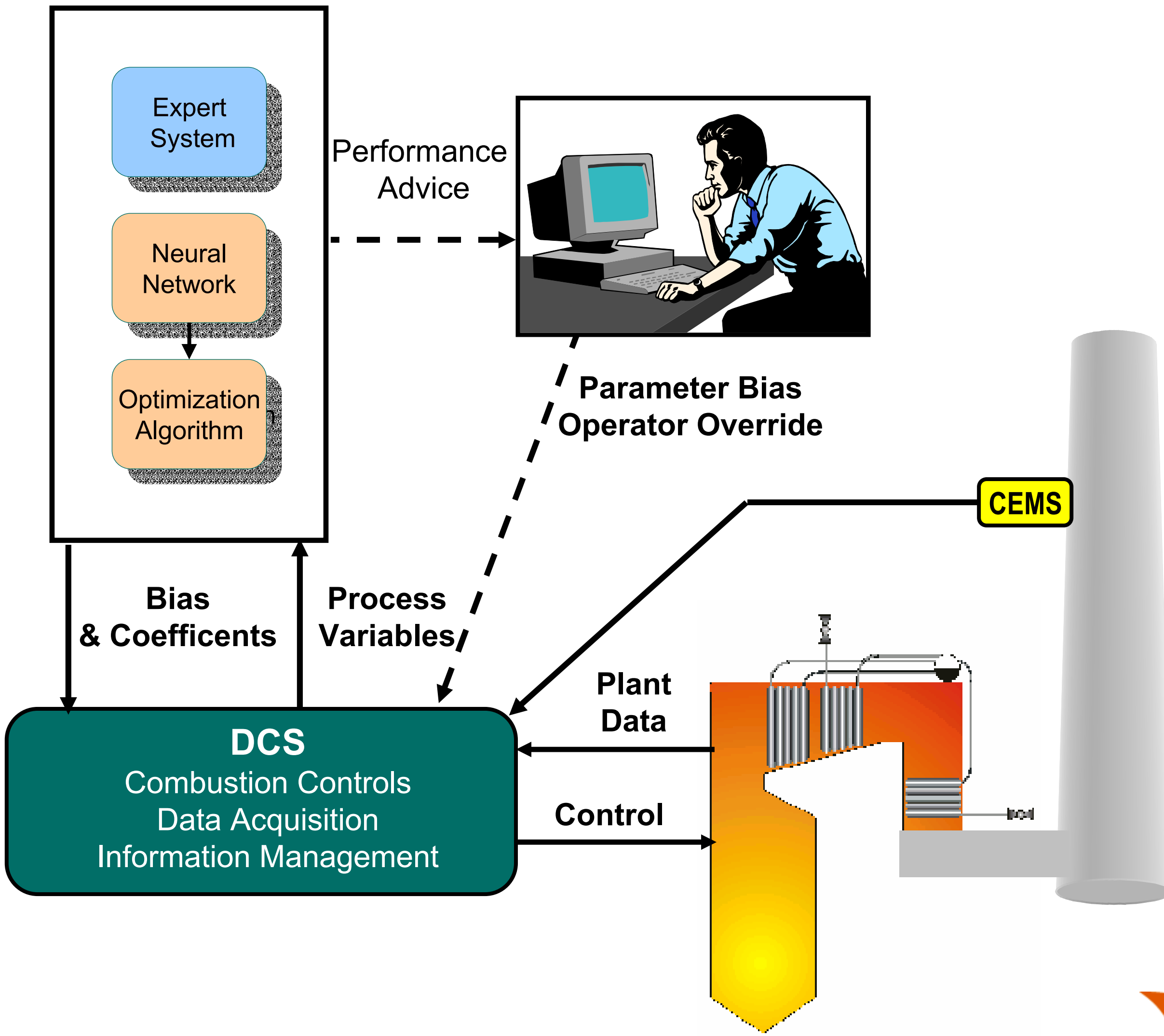


On Line Control Trim Curves

- Accounts for Day-to-Day Changes
  - Fuel Quality
  - Furnace Cleanliness
  - Equipment Condition



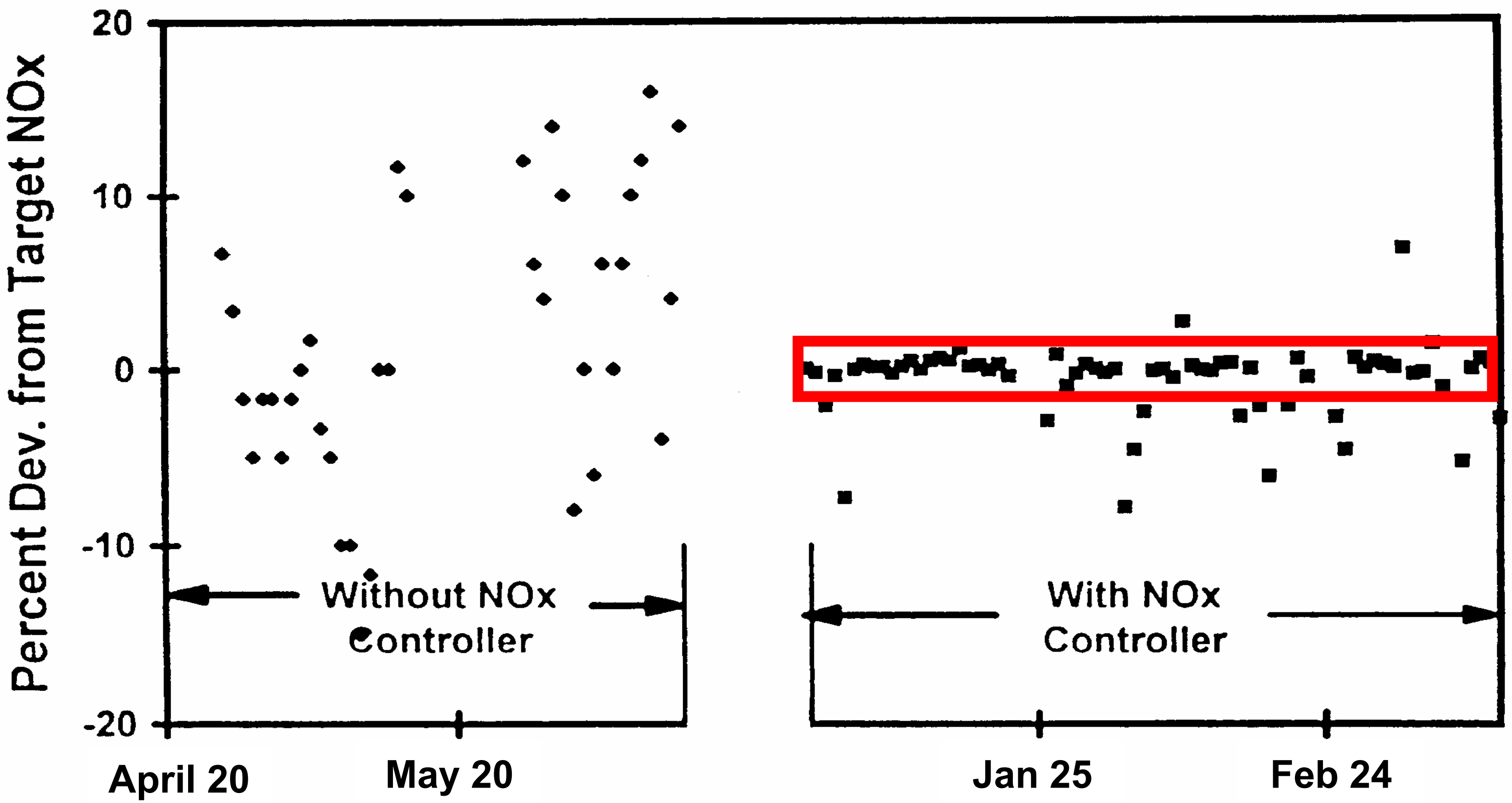
On Line Combustion Optimization



metso automation

Results with Closed Loop Control

Morgantown with LNCFS III



metso automation

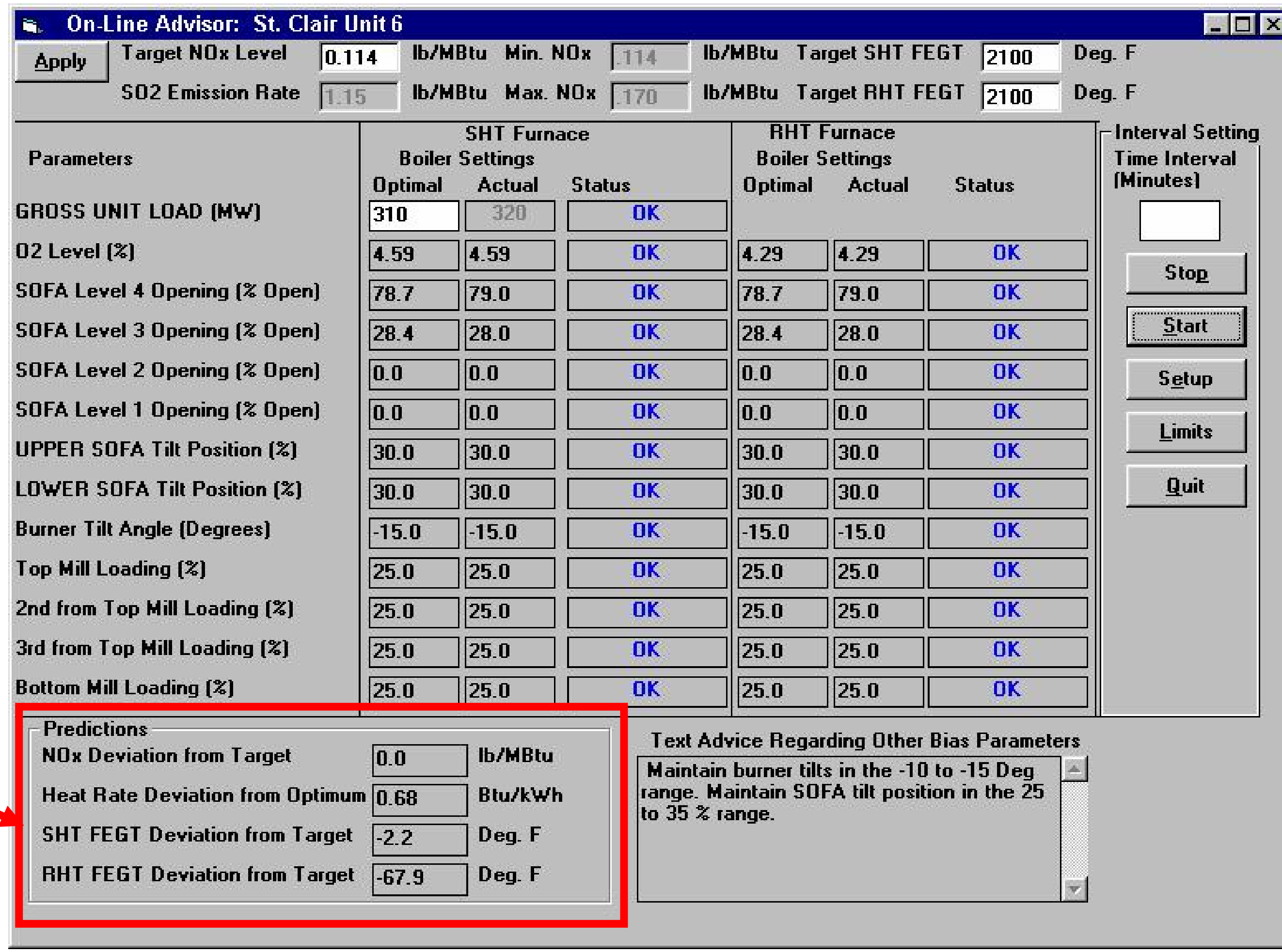
Operator Display

- Presents Optimal and Actual Boiler Settings
- “Penalty Box” shows impact of control deviations on
  - NOx
  - Heat Rate
  - LOI
- Displays Neural Network Model Limits
- Displays Status of each Key Parameter
- Allows Operator to set Update Interval

metso automation

Operator Display

T-fired Twin Furnace Example


On-Line Advisor: St. Clair Unit 6

Apply

Target NOx Level	0.114	lb/MBtu	Min. NOx	.114	lb/MBtu	Target SHT FEGT	2100 Deg. F
SO2 Emission Rate	1.15	lb/MBtu	Max. NOx	.170	lb/MBtu	Target RHT FEGT	2100 Deg. F

Parameters	SHT Furnace Boiler Settings Optimal	SHT Actual	SHT Status	RHT Furnace Boiler Settings Optimal	RHT Actual	RHT Status
GROSS UNIT LOAD (MW)	310	320	OK			
O2 Level (%)	4.59	4.59	OK	4.29	4.29	OK
SOFA Level 4 Opening (% Open)	78.7	79.0	OK	78.7	79.0	OK
SOFA Level 3 Opening (% Open)	28.4	28.0	OK	28.4	28.0	OK
SOFA Level 2 Opening (% Open)	0.0	0.0	OK	0.0	0.0	OK
SOFA Level 1 Opening (% Open)	0.0	0.0	OK	0.0	0.0	OK
UPPER SOFA Tilt Position (%)	30.0	30.0	OK	30.0	30.0	OK
LOWER SOFA Tilt Position (%)	30.0	30.0	OK	30.0	30.0	OK
Burner Tilt Angle (Degrees)	-15.0	-15.0	OK	-15.0	-15.0	OK
Top Mill Loading (%)	25.0	25.0	OK	25.0	25.0	OK
2nd from Top Mill Loading (%)	25.0	25.0	OK	25.0	25.0	OK
3rd from Top Mill Loading (%)	25.0	25.0	OK	25.0	25.0	OK
Bottom Mill Loading (%)	25.0	25.0	OK	25.0	25.0	OK

Interval Setting

Time Interval (Minutes)

Stop

Start

Setup

Limits

Quit

Predictions

NOx Deviation from Target	0.0	lb/MBtu
Heat Rate Deviation from Optimum	0.68	Btu/kWh
SHT FEGT Deviation from Target	-2.2	Deg. F
RHT FEGT Deviation from Target	-67.9	Deg. F

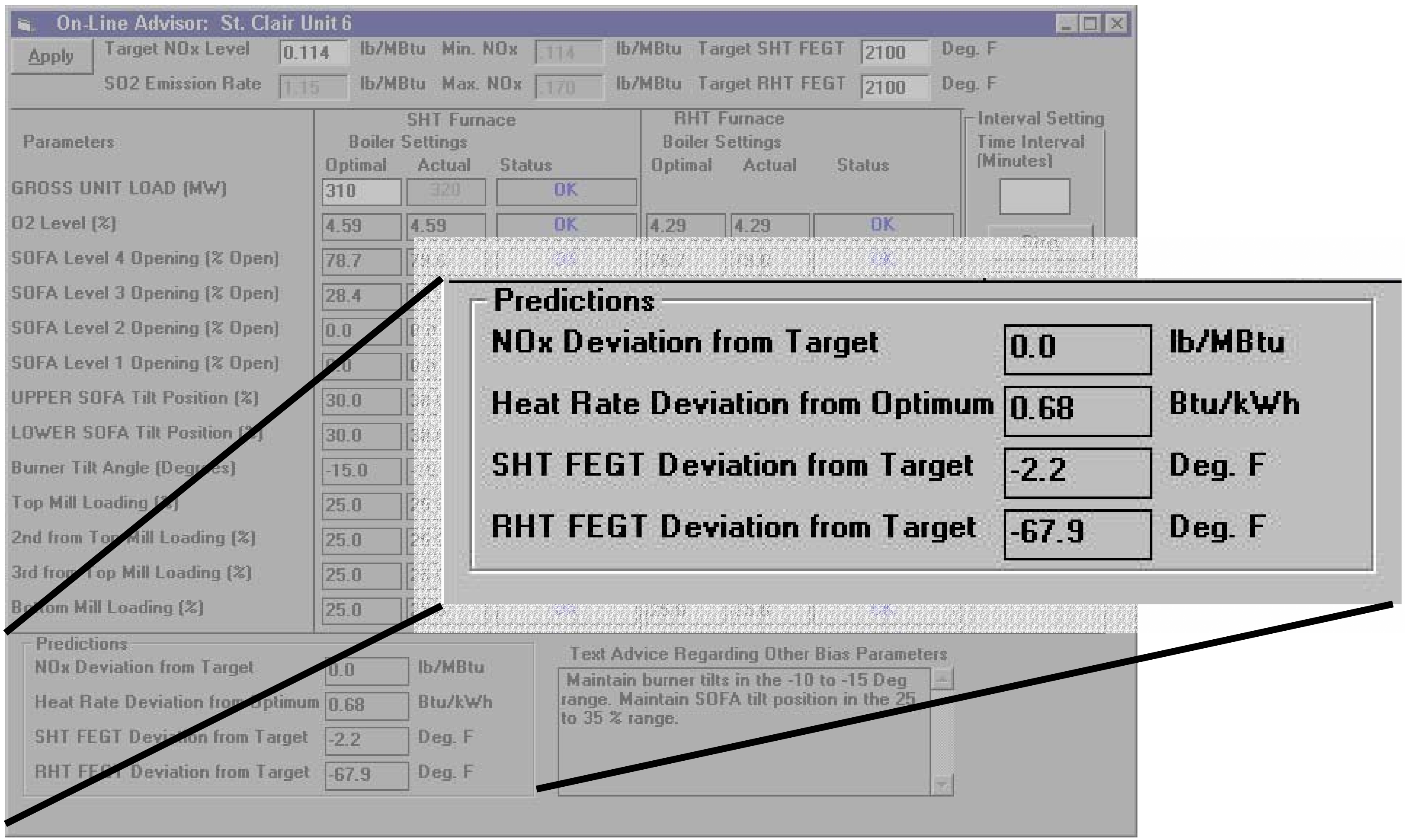
Text Advice Regarding Other Bias Parameters

Maintain burner tilts in the -10 to -15 Deg range. Maintain SOFA tilt position in the 25 to 35 % range.

Penalty Box

metso automation

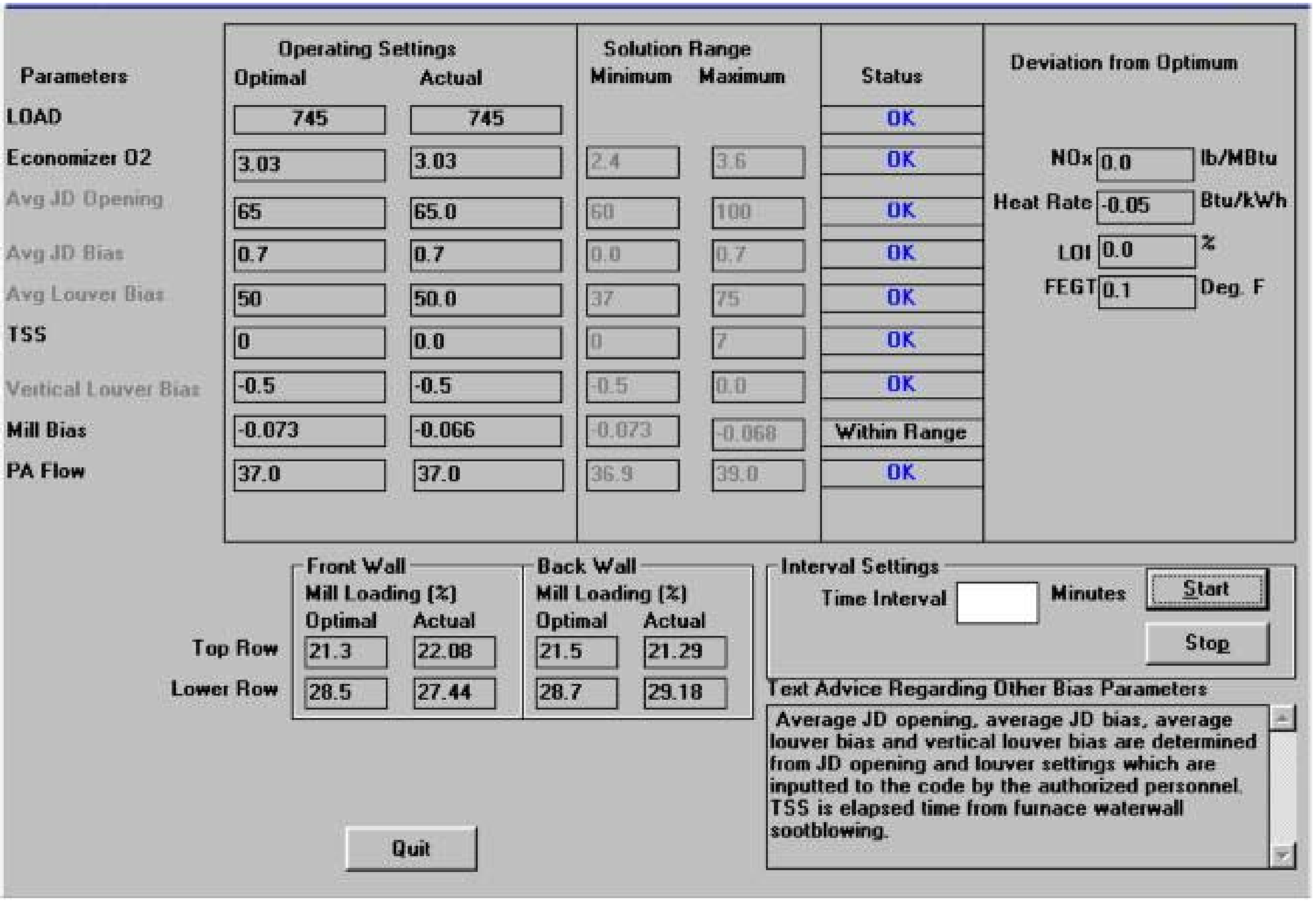
Penalty Box Example



metso automation

Operator Display

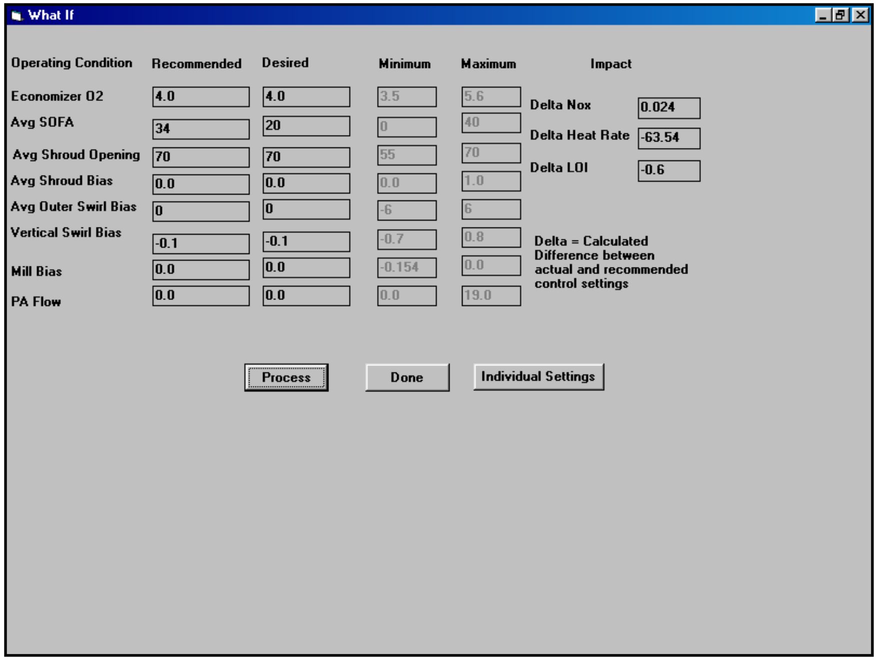
Wall Fired Example



metso automation

“What If”Analysis

- An optional engineering & training tool
- Allows manual entry of “Actual” data
- Shows impact of deviations from optimal settings on
  - NOx
  - Heat Rate
  - LOI
  - CO



What if the Optimization Objectives, Constraints, or Operating Conditions Change?

Example:

Objective is now to minimize LOI at Target NOx

- New Optimal Solutions can be calculated with the same Neural Network Model developed from the parametric tests
- New Control Curves can be configured in the Combustion Control System

metso automation

FIELD RESULTS

Boiler Types

- 4 Corner-Fired Boiler with Conventional Burners
- 4 & 8 Corner-Fired Boilers with Low-NOx Firing Systems
- Wall-Fired Boiler with Dual Register Burners and OFA
- Wall-Fired Boiler with Flue Gas Recirculation Systems
- Arch-Fired Boiler with Conventional Burners

Fuel Types

- Eastern Bituminous Coal
- Western Sub-bituminous & PRB Coals
- Coal Blends (Eastern & Western Coals)
- Lignites
- Anthracite
- Oil
- Gas & Gas Co-firing
- Landfill Gas & Coal Co-firing

metso
automation

FIELD RESULTS
T-FIRED UNITS

Boiler Characteristics	Fuel Type	Unit Load (MW)	Baseline NOx (lb/ MBtu)	NOx Reduction (%)
Four-Corner Boiler with Conventional Burners.	EC	4X108 1X150	0.60	25
Eight-Corner Boiler with LNCFS-III Low-NOx Burners.	EC	585	0.75	40
Four-Corner Boiler with LNCFS-III Low-NOx Burners.	EC	92	0.45	22
Twin-Furnace Boiler with LNCFS Low-NOx Burners.	EC	315	0.30	23
Eight-Corner Boiler with LNCFS-III Low-NOx Burners.	EC	2X250	0.36	31
Eight-Corner Boiler with Low-NOx Burners and Overfire Air (OFA).	EC,WC	510	0.22	8
Eight-Corner Boiler with Separate SHT and RHT Furnaces. Low-NOx Burners and Overfire Air (OFA).	EC,WC	240	0.22	38

Fuel Types: EC- Eastern Coal, WC - Western Coal

metso automation

FIELD RESULTS
WALL FIRED UNITS

Boiler Characteristics	Fuel Type	Unit Load (MW)	Baseline NOx (lb/ MBtu)	NOx Reduction (%)
Opposed Wall-Fired Boiler with Dual Register Low-NOx Burners and OFA.	EC	650	0.75	20
Front Wall-Fired, Twin-Furnace Boiler with Conventional Burners.	EC, WC, G	280	1.13	31
Opposed Wall-Fired with Dual Register Burners.	WC	600	0.24	34
Front Wall-Fired Boiler with Conventional Burners.	EC, WC, O	150	0.68	29
Front Wall-Fired with Conventional Burners and Flue Gas Recirculation.	EC	2X300	1.11	15-35
Opposed Wall-Fired with Low-NOx Cell Burners.	EC, WC	750	0.67	33
Opposed Wall-Fired Boiler with DRB-XCL low-NOx Firing System with OFA	EC	630	0.47	27

Fuel Types: EC- Eastern Coal, WC - Western Coal, O - Oil, G - Gas

metso automation

PEPCO Potomac River

- Four 108 MW & one 150 MW Units
- Tangentially-Fired Pulverized Coal
- Conventional Burners – Original Firing System
- Eastern Bituminous Coal
- Four Burner Elevations – All Four Mills Needed to Achieve Full Load
- Optimization Objective – Meet NOx Regulations Without Converting to Low NOx Burners

Combustion Optimization Savings

PEPCO saved $37 Million

by Avoiding Low-NOx Burners

Powered by …..
Metso - a leading world-wide supplier to the electric power industry

metso
automation